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Electron spin dephasing by hyperfine interaction with nuclei in quantum dots[1]

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The problem of the dynamics of an electron spin coupled by hyperfine (hf) interaction to nuclear spins has been a focus of large theoretical attention, since the interaction with the nuclear bath is the most limiting decoherence mechanism in spin qubits based on quantum dots made of III-V materials. I will present a theory of pure dephasing decoherence which gives predictions for electron dynamics in narrowed state free induction decay, spin echo, and under higher order dynamical decoupling sequences [1,2]. In this theory we take advantage of the long-range character of hf-mediated interactions (which couple remote nuclei via virtual flip-flops with the electron spin), and we resum the leading terms in 1/N expansion of the decoherence time-evolution function (N being the large number of nuclei interacting appreciably with the electron spin). For the case of a thermal uncorrelated bath this approach is applicable as long as the electron Zeeman splitting is larger than the typical Overhauser shift of the electron energy (i.e. magnetic field must be larger than a few mT in a large GaAs dot). For the spin echo evolution we show that the dominant decoherence process at low fields is due to interactions between nuclei having different Zeeman energies (i.e. nuclei of As and two isotopes of Ga in GaAs). The robustness of this theory is verified by comparison with a numerical simulation of spin echo in a system with $N = 20$ nuclei. I will also discuss the application of our approach to singlet-triplet qubit in a double quantum dot.

[1] L. Cywinski, W.M. Witzel, and S. Das Sarma, Phys. Rev. Lett. **102**, 057601 (2009).
[2] L. Cywinski, W.M. Witzel, and S. Das Sarma, Phys. Rev. B **79**, 245314 (2009).

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